On Decentralized Self-Adaptation: Lessons from the Trenches and Challenges for the Future

Danny Weyns, Sam Malek, Jesper Andersson
SEAMS 2010, Cape Town
Motivation

• Lack of understanding on how to engineer distributed self-adaptive software systems in which central control is not possible
• Important for domains in which no entity has the required knowledge or the authority to perform adaptations
Approach

1. We identified key attributes of decentralized self-adaptive systems (literature study + our own experience)
2. We illustrated these attributes in two case studies
3. We generalized the lessons learned in the form of a high-level reference model
4. We identified a number of challenges that are subject for future research
Overview

• Model for self-adaptive systems
• Key attributes of decentralized self-adaptive systems
• Case study
• Reference model
• Challenges ahead
Self-Adaptive System

Self-Adaptive System*

Self-Adaptive System*

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Key Attributes of Decentralized Self-Adaptive Systems

- Decentralized self-adaptive system = self-adaptive system in which
  - there is no central point of control
  - no global knowledge on any of the host
- To realize adaptations, computations of self-adaptive units have to coordinate
Key Attributes of Decentralized Self-Adaptive Systems

- **Coordinated monitoring**
  - monitor computations may need to coordinate to share and synchronize locally collected data

- **Coordinated analysis**
  - self-adaptive units may need to coordinate to evaluate adaptation options with one another
Key Attributes of Decentralized Self-Adaptive Systems

- **Coordinated planning**
  - Plan computations may need to coordinate to construct an adaptation plan that satisfies the different goals

- **Coordinated execution**
  - Self-adaptive units may need to coordinate to synchronize the adaptations to the system
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Case Study: Deployment Improvement Framework

- General overview

Diagram:

- Deployment Improvement Framework
  - Analyzer
  - Effector
  - Algorithm
  - Model
  - Monitor
  - User Input
  - Implementation Platform
  - System Architect

Legend:
- Host
- Component
- Data flow

Plan + Analysis + Concern model

Self-adaptive unit

Execute

Subsystem model

Managed subsystem
Case Study: Deployment Improvement Framework

- Distributed, centralized instantiation
Case Study: Deployment Improvement Framework

- Decentralized instantiation
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Reference Model
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Challenges ahead

• **Conflicting goals**
  - Self-adaptive units may pursue their own goals
  - Conflicts may result from sharing resources
  - Market mechanisms, trust, learning techniques

• **Uncertainty**
  - Due to partial knowledge and system’s organization dynamics (self-adaptive units join/leave dynamically)
  - Artificial self-organizing systems have shown to be particularly robust to dynamics
Challenges ahead

• Overhead
  ▫ Coordination requires additional communication and computation
    • Partial knowledge: share local information
    • Conflicting goals: coordinate through negotiation

  Two key issues
  • Efficiency of resources utilization
  • Timing of making and effecting adaptations
Challenges ahead

• Systematic engineering
  ▫ Need a better understanding of the trade-offs among the design decisions
    • E.g., selecting coordination mechanisms taking into account overhead and level of guarantees desired
  ▫ How to apply principles of software architecture to the organization of such systems?
    ➤ Starting point: patterns for agent-based organizations
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